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**CCMTA Load Security Research Project**

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**Report # 19**

**ASSESSING A SECUREMENT  
METHOD FOR THE TRANSPORTATION  
OF HEAVY MACHINERY USING A  
COMBINATION OF HIGHWAY VEHICLES**

*Prepared for*

Canadian Council of Motor Transport Administrators  
Load Security Research Management Committee

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## **North American Cargo Securement Standard**

CCMTA is serving to coordinate the development of a revised North American Cargo Securement Standard. To this end the research results in this report are being reviewed and discussed by interested stakeholders throughout North America.

**Those readers interested in participating in the development of the North American Cargo Securement Standard through 1997 are invited to visit the project Web site at [www.ab.org/ccmta/ccmta.html](http://www.ab.org/ccmta/ccmta.html) to secure additional project information.**

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In the fall of 1995, the Quebec Department of Transport commissioned studies to assess the static and dynamic behaviour of highway vehicle combinations of oversized weight. The Department took advantage of this opportunity to carry out parallel studies on the method used to tie down the load in this type of transportation. Both studies were carried out by Camtech Consultants Inc., under the direction of Project Officer Jean Grandbois, ing.

This report is divided into three main sections. The first section provides a general overview of the vehicles, the load, the securement method and the instrumentation. The second section deals with static testing, while the third deals with dynamic testing. The last two sections are divided into three subsections as follows: tests and measurements, results, analysis.

This study of the securement method used for specialty vehicles represents additional research carried out by the Quebec Department of Transport within the larger framework of securement studies implemented jointly by a number of North American agencies.



Photo 1: Vehicle combination, with load.

## **2. Vehicles, Load, Securement Method and Instrumentation**

### **2.1 Vehicles**

The tests were carried out with a combination of vehicles consisting of a tractor and a semi-trailer with a double drop lowbed. The tractor was a Mack 1995 equipped for extra-heavy road transportation, with a 1.52 m tandem. The semi-trailer with the double drop lowbed had a rated capacity of 54,400 kg (60 tons). The flatbed had sides that were low in terms of the chassis, with a width of 2.60 m. The tridem spacing was 3.04 m. The combination of vehicles, weighing 22,640 kg, belonged to Transport Camille Dionne (1991) Inc., of Laval.

### **2.2 Load**

The load used for the tests was a CAT 235C power shovel provided by Hewitt Équipement Ltée. of Pointe-Claire. The shovel with its counterweight and bucket weighed 46,680 kg. The articulated arm rested slightly to the rear of the semi-trailer, whereas the metal crawler tracks rested on the sides of the lowbed, covered with hardwood.

### 2.3 Securement Method

A transportation-type chain of 10 mm (3/8 in), grade 7 (or 70 depending on the manufacturer), was used for securement purposes in the tests. The chains had a working load limit of 29.4 kN (6,600 lb) and they were tested by the manufacturer at twice that limit. Moreover, the minimum ultimate load, which is the minimum weight under which a chain will break in a test, was four times the working load limit. The minimum ultimate load can also be considered as the official safety coefficient.

For testing purposes, the chains used to tie down the power shovel were set up in three different ways, on two levels. A first series of chains (first level to hold down the load) was set up in cross-over fashion (from the top edge of the crawler track to the side of the semi-trailer chassis) under tension, at the front and rear of the power shovel, using current Quebec practices. These chains were instrumented. A second series of chains (initial safety) was set up in the same way, but with a certain amount of slack that would be taken up only if the first series of chains failed. Finally, big chains (1/2 in and 5/8 in) were also installed with the same amount of slack between the main part of the shovel and the chassis of the double drop lowbed (double safety). The anchor points for the safety chains had a higher rating than the chains themselves. The position of the chains is shown in Figure 1.

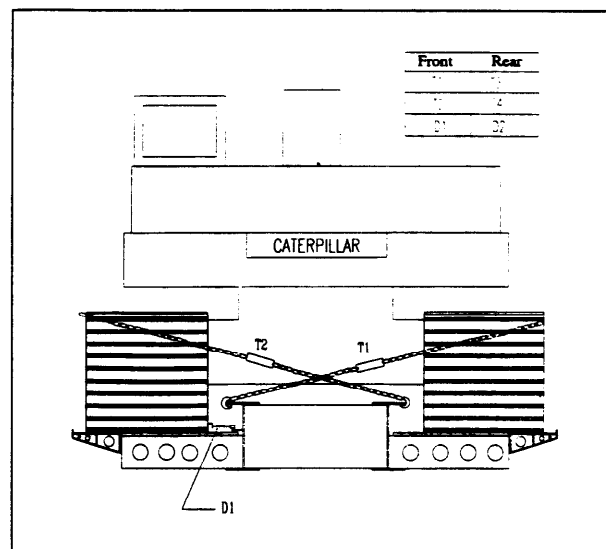


Figure 1: Position of the chains and instrumentation

## 2.4 Instrumentation

Two types of instruments were mounted on the securement equipment and the load. Four strain gauges were set up on the tensioned chains tying down the power shovel itself. Three displacement indicators (two for the static tests) were placed on the flatbed to measure the lateral displacement (front and rear) or the longitudinal displacement (dynamic test only) of the power shovel. These instruments were linked to a computer that recorded, as a function of time, both tension and displacement data.

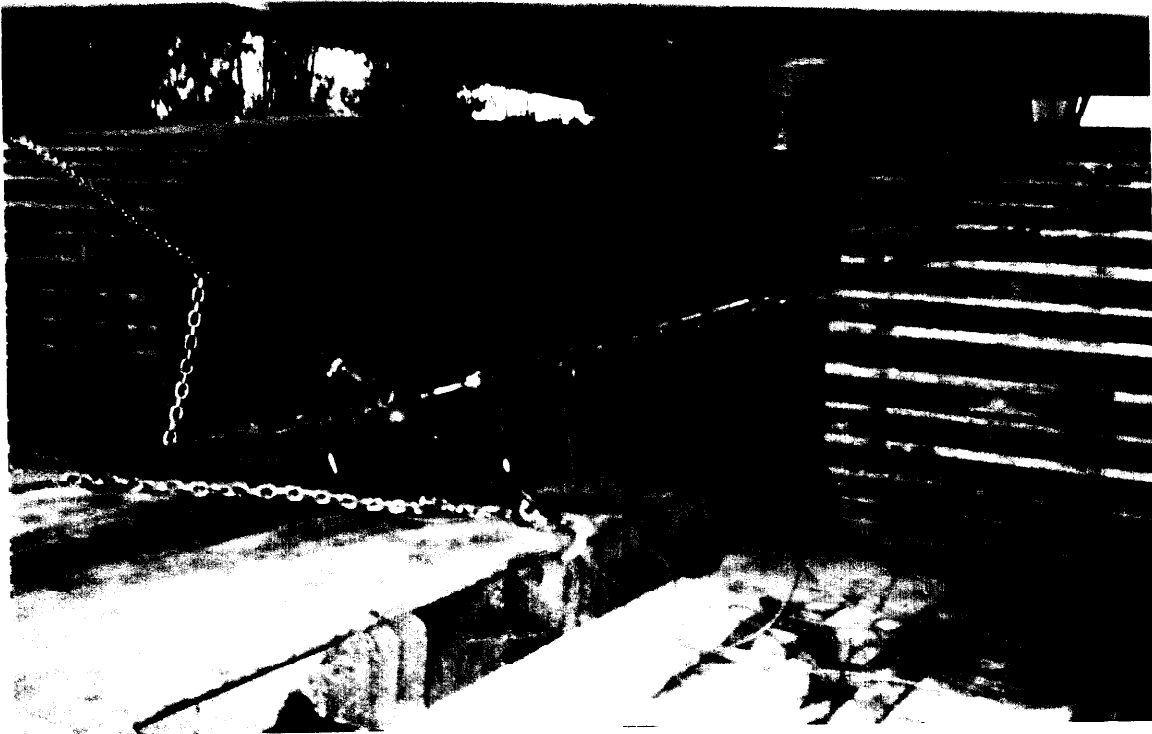


Photo 2: Strain gauges mounted on the chains.

Strainert strain gauges were used, consisting of model 5/8"-11 studs with an internal strain gauge. They had a capacity of 66.7 kN (15,000 lb) for linear readings, and a resistance of 133 kN. These strain gauges were provided by the Ontario Ministry of Transportation.

Three Magnatek position transducers (model PV-15) were used, providing an accuracy in the order of one-tenth of a millimetre. They belonged to the National Research Council of Canada.

### **3. Static Testing**

#### **3.1 Description of the Tests**

The static tests were carried out on NRC's roll-over table in Ottawa. This roll-over table consisted of a large platform, one side of which was articulated while the other side could be raised using hydraulic jacks. The tilt of the table simulated the lateral acceleration to which a vehicle would be subjected in a curve. Three roll-over tests were carried out. The tension in the four cross-over chains as well as the displacement were measured in terms of equivalent lateral acceleration.



Photo 3: Test vehicles on the roll-over table.

#### **3.2 Results**

The results, shown in Table 4 of Appendix 1, were taken from the lateral load transfer, tension and position graphs recorded in terms of equivalent lateral acceleration (or table tilt). There was one graph per instrument per test. An example of each of the three types of graphs will be found in the appendix.

In Table 4 of Appendix 1, four tension values are provided for a detailed assessment of the forces acting on the chains. These are the initial tension induced in the chain by the turnbuckle, the maximum or minimum tension once the table reaches its maximum tilt, and the final tension at the end of the test once the table has resumed its horizontal position. Since the four chains formed a cross-over pattern, only two of them held down the shovel when the table was tilted, and these were subjected to maximum tension. The other two, on the opposite side, were under less tension than in the horizontal position and were thus under minimum tension.

The lateral position of the load is given for the front and rear of the power shovel in terms of the initial, maximum and final positions. The initial position is that recorded at the beginning of the test, the maximum position is the furthest one reached during the test, and the final position is the position of the shovel once the roll-over table has resumed its horizontal position. The spread is the difference between the maximum and initial positions. It therefore represents the maximum displacement observed for that test.

### 3.3 Analysis

Initial analysis showed that the tension in the chains and the displacement of the load were not linear in terms of the equivalent lateral acceleration during the entire test, or for a lateral acceleration of 0 to 0.47 g (or less). For a value of approximately 0.3 g, the tension was relatively linear without however being directly proportional. Beyond that value, the tension increased more or less exponentially. The displacement was very low (almost inexistent) under 0.3 g, whereas it increased rapidly (without ever becoming significant in absolute terms) once that value was exceeded.

The working load limit (29.4 kN or 6,600 lb) of the chains which were subjected to increased tension was exceeded five times out of six. The three most critical occurrences were at 0.25 g, 0.26 g and 0.32 g of equivalent lateral acceleration, with an initial tension of about 15 kN. On the other hand, the capacity of the chains as tested by the manufacturer (at least twice this rated value) was never exceeded during static testing. The tension in the rear chains was higher than at the front. This is probably linked to the longitudinal position of the load's centre of gravity. The three tests showed the tension in the rear chains to be about 40 kN for an equivalent lateral acceleration of 0.40 g.

The displacement during static testing was cumulative from one test to the other, i.e. the starting position for the second test was the position at the end of the first test. The final displacement for the first two tests was 6.5 mm in each case. However, the third test produced a displacement of only 1 mm, although that was the most stringent test. This leads to the conclusion that the shovel settled, taking up all the slack during the first two tests, with no further movement under lateral acceleration values corresponding to those to which it was subjected during the tests. The total lateral displacement for the three tests was 13 mm at the rear and 7 mm at the front. The final displacement at the end of each test was always slightly lower than the maximum displacement, probably because the tension in the chains caused a very slight movement of the shovel back to its original position when lateral acceleration stopped.

**Table 1: Summary of Static Testing**  
**Tractor and triple axle double drop lowbed semi-trailer with power shovel,**  
**MTC = 69,320 kg**

Measured Values	1st Test		2nd Test		3rd Test	
Max. equivalent lat. acceleration (g)	0.41		0.47		0.48	
<i>Tension in the chains (kN)</i>	spread	maximum	spread	maximum	spread	maximum
Front right tension (T1)	-20	-	-10	-	-6	-
Front left tension (T2)	13	25	19	32	16	31
Rear right tension (T3)	-5	-	-19	-	-9	-
Rear left tension (T4)	25	39	35	50	34	50
<i>Load displacement (mm)</i>	maximum	final	maximum	final	maximum	final
Front lateral displacement (D1)	2.6	1.5	7	6	3	1
Rear lateral displacement (D2)	7.5	6.5	7	6.5	2	1

Note: 1 kN = 224.8 lb

Table 1 provides a summary of analytical results for each test. The spread shows the difference in tension recorded during testing, whereas the maximum tension represents the highest value. The maximum displacement is the highest change in position recorded during the test, whereas the final displacement is the displacement of the shovel recorded after testing, when there

was no more lateral acceleration and when the tension in the chains had caused a partial return of the load to its original position. The second and third tests reached the roll-over threshold.

The maximum tension recorded during testing was 50 kN (11,240 lb), largely exceeding the rated capacity of the chains. The maximum tension spread was 35 kN, representing the maximum force actually used to secure the load. This force measured 16 kN at the front and 31.3 kN at the rear on average. Given the weight of the shovel and the lateral acceleration values, this means that roughly 25% of the centrifugal force applied around turns would be compensated by the chains mounted in cross-over fashion at the front and rear of the power shovel. The remaining force (75%) would be compensated by friction between the crawler track and the flatbed, by the friction between the bucket and the rear platform of the double drop lowbed, as well as by the chains holding down the boom of the shovel to prevent it from swivelling.

The maximum displacement exceeded the final displacement at the end of each test. The difference between the two was generally 1 mm, with a maximum value of 2 mm. The greatest maximum displacement was 7.5 mm, which is very little given the size of the power shovel and the semi-trailer (the latter having a width of 2,600 mm).

In summary, during static testing, the displacement of this kind of load was not a problem given present securement standards. The tension in the chains was more or less problematic in terms of the minimum performance required for the vehicle. Whenever the lateral acceleration exceeded 0.25 g, the tension in the chains was generally greater than the rated capacity (wll). On the other hand, during the tests, the maximum tension remained lower than the capacity tested by the manufacturer (twice the rated capacity), and less than 50% of the manufacturer's safety coefficient.

## **4. Dynamic Testing**

### **4.1 Description of the Tests and Measurements**

Dynamic testing was carried out at Transport Canada's Motor Vehicle Test Centre in Blainville in October 1995. A variety of manoeuvres were used at various speeds to assess the dynamic behaviour of heavy vehicles. In addition to the instruments normally used to assess dynamic behaviour in such tests, the vehicle was also equipped with instruments to assess securement method during the manoeuvres. The vehicle configuration, the load, the securement method and the instrumentation were the same as those used for static testing. Thus, four strain gauges were installed on the cross-over chains and three position transducers were used to measure lateral displacement at the front and rear as well as longitudinal displacement.

Three types of manoeuvres were carried out: avoidance manoeuvre, braking and constant radius testing. The avoidance manoeuvre consisted in changing lanes and returning the vehicle to its original lane. The lanes were of normal width, and the gates had a length of 30 m, so that there were 90 m in which to carry out the complete manoeuvre. The braking manoeuvre was performed in a straight line. The constant radius test consisted in driving at various speeds in a circle with a radius of 50 m.

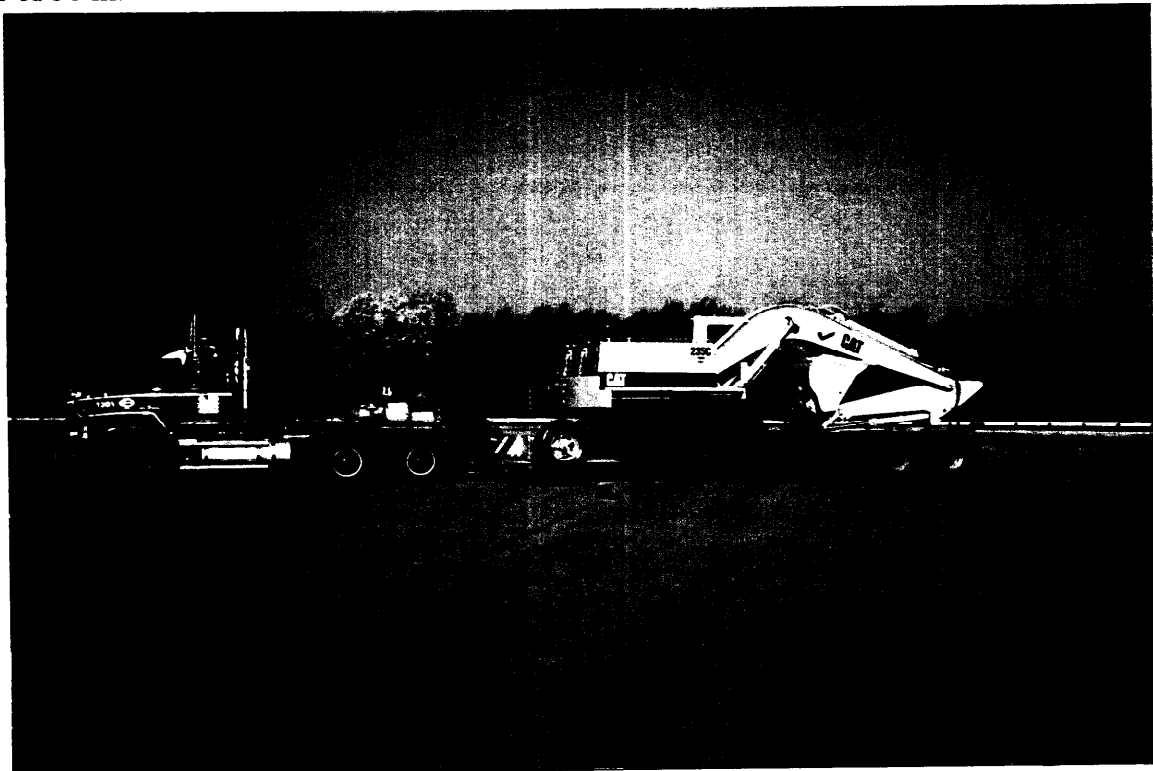


Photo 4: Vehicles on the test site.

## 4.2 Results

Complete results are provided in Appendix 4 in the same way as for static testing (initial, minimum, maximum and final tension), along with the maximum consecutive tension spread. Since the avoidance manoeuvre produced lateral acceleration in opposite directions, this measurement corresponded to the difference between the maximum tension and the minimum tension for one consecutive motion, or, in graphic terms, to the maximum spread in tension between consecutive upper and lower peaks. Positions are indicated in the same way (initial, minimum, maximum, final and maximum consecutive spread). However, for dynamic testing, unlike static testing, the maximum consecutive spread was not necessarily the maximum position minus the minimum position (the initial position for static testing) since these values were not necessarily consecutive.

There were eight avoidance manoeuvres carried out at speeds between 53 and 83.5 km/h, two braking tests at 55 and 71 km/h and, finally, three constant radius tests at speeds between 5 and 37 km/h. For each test, the data show the speed at which the manoeuvre was carried out, as well as the maximum lateral acceleration, along with the tension and the displacement.

The tension in the chains and the displacement at the beginning and at the very end of the tests are shown in Table 3.

**Table 2: Initial and Final Measurements of Dynamic Tests**

Measurements	Initial	Final
Front right tension (T1)	14.2 kN	11.1 kN
Front left tension (T2)	18.7 kN	14.6 kN
Rear right tension (T3)	6.7 kN	6.0 kN
Rear left tension (T4)	8.45 kN	4.2 kN
Front lateral displacement (D1)	-	0.6 mm
Rear lateral displacement (D2)	-	0.2 mm
Longitudinal displacement (D3)	-	0 mm

In all cases, the tension indicated by the final values was lower than the initial value. The drop in tension was 26% on average for the four chains. These results confirm the importance of checking and increasing, if need be, the tension in securement systems after covering a certain distance.

### 4.3 Analysis

To make the data easier to read, the maximum values reached in each type of test are summarized in the following table. The spread shows the difference in tension observed for two consecutive motions within a given manoeuvre, whereas the maximum tension is the maximum value reached during the test. The maximum displacement is the absolute value of the greatest difference in position between two consecutive displacements, whereas the final displacement is the difference between the final position and the position recorded at the beginning of the same test.

**Table 3: Summary of Dynamic Testing**

**Tractor and triple axle semi-trailer with power shovel, MTC = 69,320 kg**

	Acceleration	Tension in kN		Displacement in mm	
	g	spread	maximum	maximum	final
Avoidance manoeuvre	0.37	29.8	29.8	2.5	0.5
Braking	0.32 long.	13.4	23.4	0.9	0.3
Constant radius	0.09/0.10	6.7	22.0	0.4	0.4

Maximum tension and displacement were reached during an avoidance manoeuvre at 83.5 km/h. This manoeuvre was not successful, and no attempt was made at a higher speed since the vehicle was on the verge of losing control. This probably equalled or exceeded the extreme conditions that a vehicle of this type could be expected to withstand on an open highway without having an accident.

As for the braking tests, the acceleration shown is the longitudinal deceleration of the vehicle. Two lateral acceleration values are shown for the constant radius tests since the tension values were reached at 0.09 g and the displacement values at 0.10 g during a different test.

The maximum tension value observed during dynamic testing was 29.8 kN, which is very slightly higher than the working load limit (29.4 kN). This tension was reached during a manoeuvre which would probably have caused an accident if the tractor-trailer combination had been driven by someone with average experience and ability on an open highway. The maximum tension reached during dynamic testing was therefore lower by a significant amount to values observed during static testing. This can be readily explained by the lateral acceleration levels for the tests (0.41 to 0.48 g for static testing versus 0.37 g for dynamic testing).

For the avoidance manoeuvres, note that the curves for the right and left chains are inverted symmetrically. The tension in the chains never dropped below 0.5 kN when the speed was less than 70 km/h. On the other hand, beyond that speed, the tension dropped regularly to 0. As a rule, the original tension was recovered at the end of the manoeuvre (the difference was less than 4.5 kN if observed at all). For an equivalent lateral acceleration, the maximum tension was lower for tests carried out on the test site as compared to those carried out on the roll-over table. On the other hand, the difference in tension was more significant during dynamic testing. This can probably be explained by the length of time during which lateral acceleration was applied, as well as by the fact that the tension in the chains returned to zero during a number of dynamic tests, unlike what occurred during static tests.

As for constant radius testing, the difference in tension observed for an equivalent lateral acceleration was relatively similar for static and dynamic tests. Likewise, maximum tension values were also of the same magnitude, with differences mainly due to the initial tension. This similarity is normal since the constant radius test is the driving test most similar to the roll-over table test, given the continuous and progressive lateral acceleration.

## **5. Conclusion**

First of all, it is important to note that load displacement was very low or nonexistent during all the tests, be they static or dynamic. Emphasis should therefore be focused chiefly on the capacity of the chains to withstand the tension to which they are subjected.

Concerning static testing, for equivalent lateral acceleration values greater than 0.4 g, the working load limit was routinely exceeded. A vehicle can withstand an equivalent lateral acceleration of about 0.25 g before the chains exceed their rated capacity. On the other hand, the capacity tested by manufacturers (twice the working load limit) was never exceeded.

As for dynamic testing, the measured tension was for the most part lower than the working load limit. This is chiefly due to the fact that the tests were less stringent in terms of lateral acceleration since the vehicles had to be kept under control at all times.

In order to determine whether the securement methods presently used in Quebec for double drop lowbed semi-trailers are sufficient, it is necessary to establish the minimum performance level and the safety coefficient deemed necessary by the authorities. Must we strive to reach without difficulty a performance level of 0.40 g, such as that targeted for regular traffic, even if the probability that a specialty vehicle will reach such an acceleration without an accident is very slight?

The securement method used at present for power shovels is, in terms of daily experience, fairly well suited to existing needs. This has been confirmed by the results of dynamic testing. On the other hand, dynamic tests were carried out under excellent conditions (flatbed and crawler track free of mud and ice, etc.), on a beautifully surfaced test site with no holes nor bumps, a situation not always encountered on highway infrastructures. Higher stress levels could be expected on a load carried during similar manoeuvres under normal road conditions. In such a case, the working load limit would quickly be exceeded since there was not a large spread between the results observed and that limit.

Moreover, the friction coefficient between the crawler tracks and the flatbed of the semi-trailer is very significant in terms of the forces transferred to the securement chains for this type of load. Static tests showed that roughly 75% of the centrifugal acceleration was compensated by frictional forces. Tests carried out during this study were not aimed at determining precisely

the friction coefficient. It is nevertheless certain that the results obtained (tension in the securement equipment and displacement of the load) would be directly affected by a change in the friction coefficient. Results of other studies carried out during the overall research project now being implemented in Canada might provide further information on this issue.

We must therefore decide at what percentage level the official manufacturer's safety coefficient (indicated on the rating tables) must be set in terms of securement capacity. For a performance of 0.30 g, there was very little emphasis on this during dynamic testing, but the limit was 0.25 g for static testing. For a dynamic performance of 0.35 g, the rated capacity of the chains was constantly reached or exceeded. If it were necessary to reach a lateral acceleration performance of 0.40 g, it would be necessary to double the cross-over chains or to install two more securement devices.

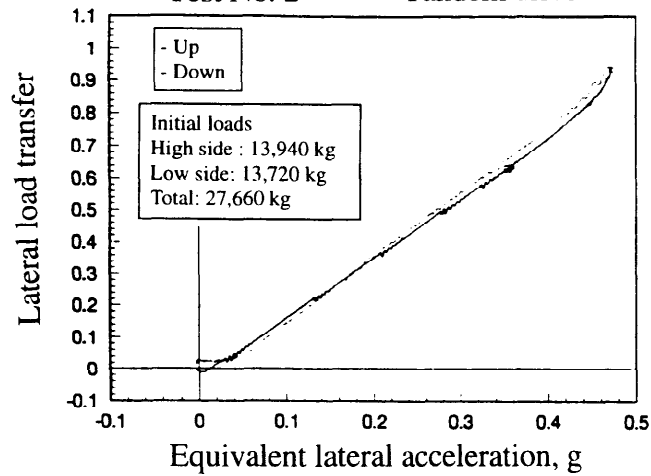
Finally, it would be important to ensure that all the securement devices, including the turnbuckles and hooks, have a capacity equal to or greater than that of the chains, which is not always the case.

## **APPENDICES**

## APPENDIX 1

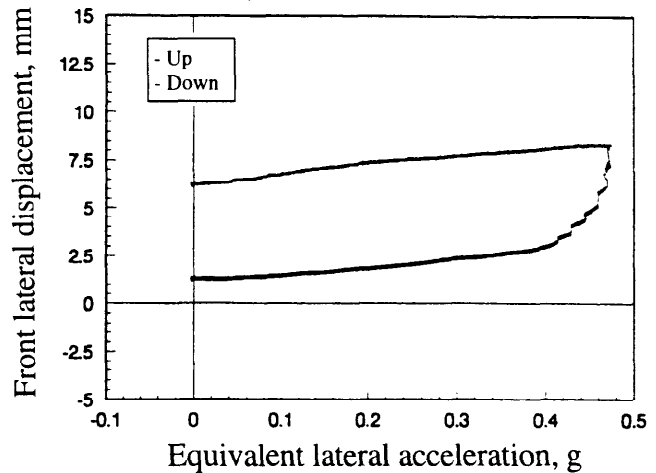
Camtech Consultants Inc.  
Tractor-trailer combination

Test No. 2 Tandem drive



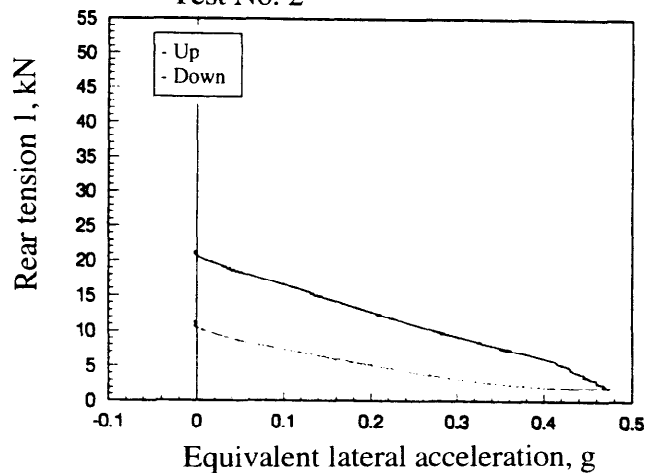
Camtech Consultants Inc.  
Tractor-trailer combination

Test No. 2



Camtech Consultants Inc.  
Tractor-trailer combination

Test No. 2



Camtech Consultants Inc.  
Tractor-trailer combination

Test No. 2

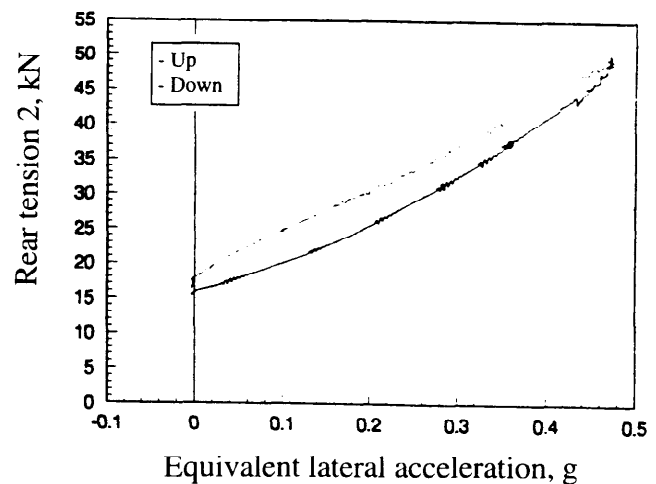


Figure 2: Examples of lateral load transfer, tension and position graphs as a function of equivalent lateral acceleration.

## APPENDIX 2

Table 4: Results of Static Testing

Tractor and triple axle double drop lowbed semi-trailer with power shovel, MTC = 69,320 kg

*International System*

Measured Values	1st Test				2nd Test				3rd Test			
Max. equivalent lat. acceleration (g)	0.41				0.47				0.48			
<i>Tension in the chains (kN)</i>	initial	maximum	minimum	final	initial	maximum	minimum	final	initial	maximum	minimum	final
Front right tension (T1)	23	-	3	9.5	10	-	0	6	6	-	0	5.5
Front left Tension (T2)	12	25	-	14	13	32	-	15	14	31	-	14
Rear right tension (T3)	5	-	0	0.5	21	-	2	11	11	-	2	9
Rear left tension (T4)	14	39	-	14	15.5	50	-	18	16	50	-	13
<i>Load position (mm)</i>	initial	maximum	spread	final	initial	maximum	spread	final	initial	maximum	spread	final
Front lateral position (D1)	0	3.0	3.0	1.5	1.5	8.5	7	6	6	9	3	7
Rear lateral position (D2)	0	7.5	7.5	6.2	6.2	12	5.8	12	12	14	2	13

Note: 1 kN = 224.8 lb

## APPENDIX 3

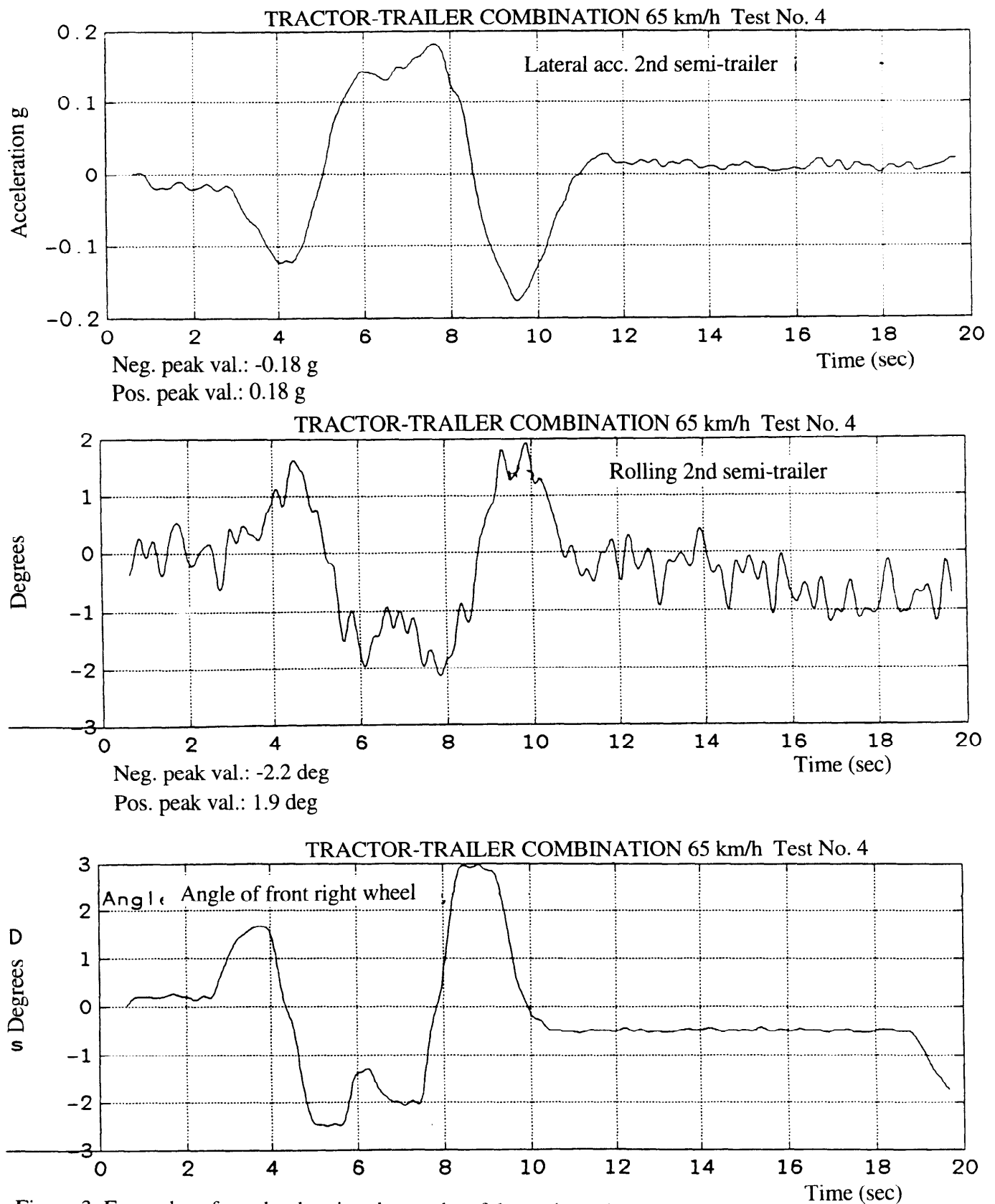


Figure 3: Examples of graphs showing the results of dynamic testing.

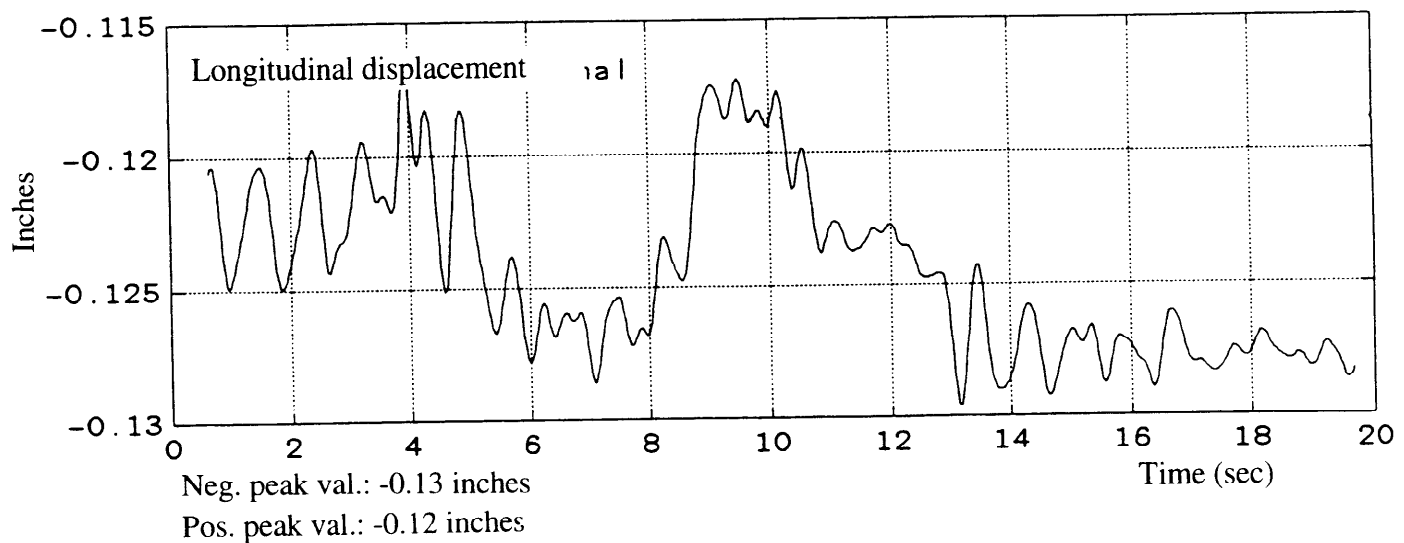
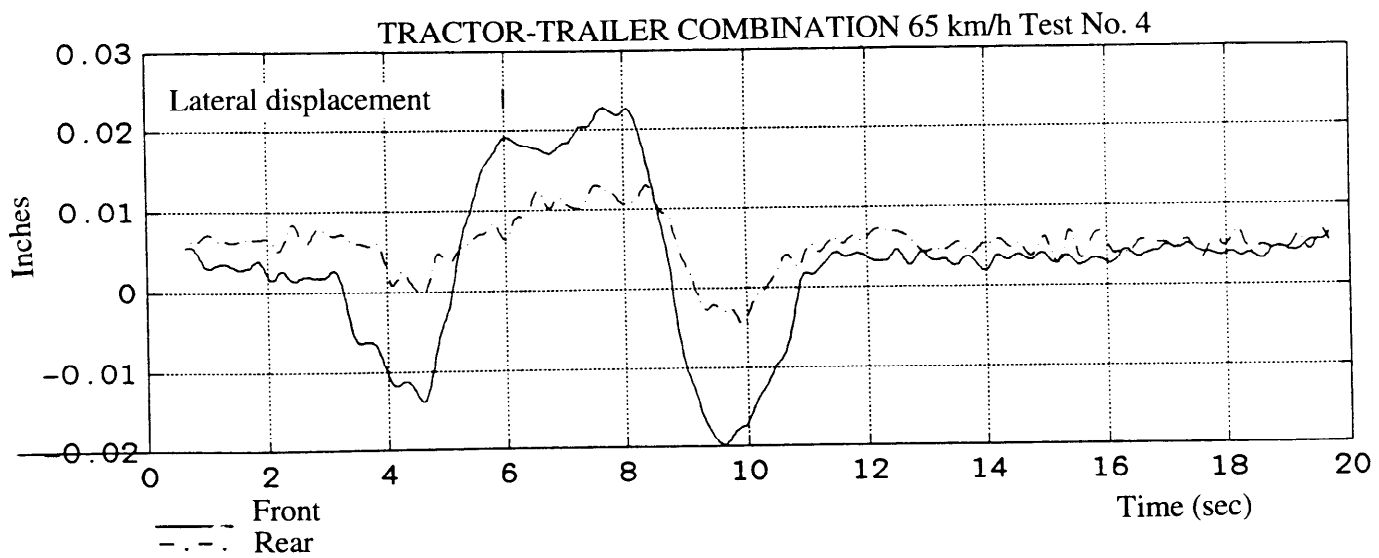
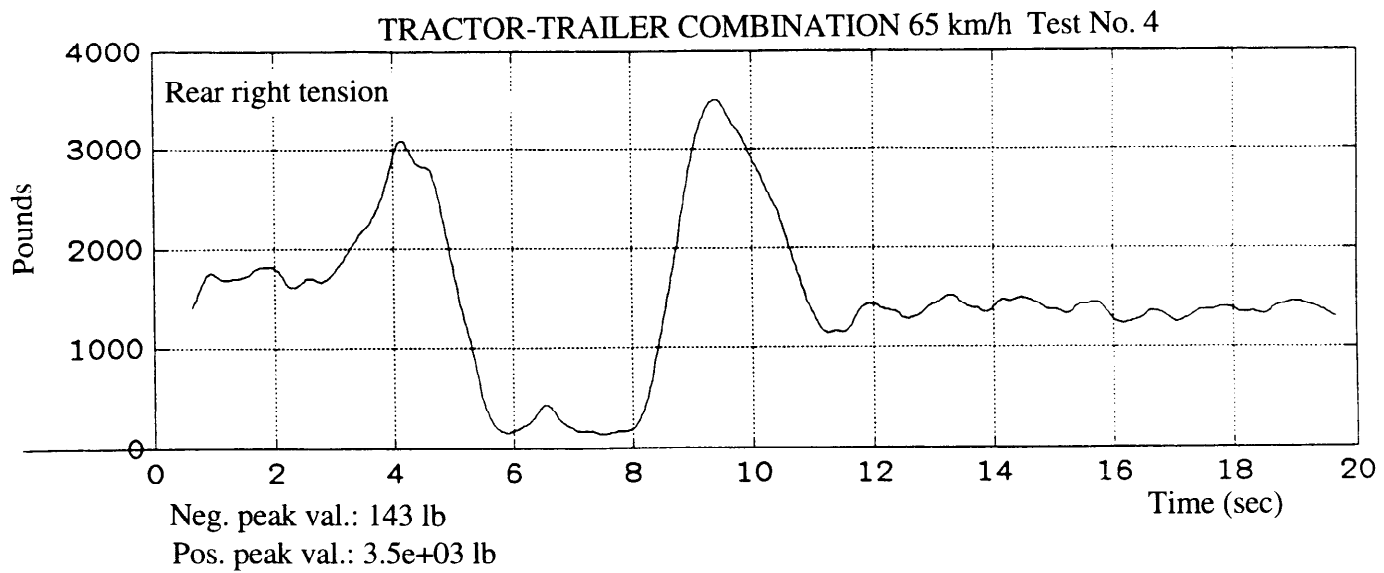


Figure 3: Examples of graphs showing the results of dynamic testing (cont'd).

## APPENDIX 4

Table 5: Results of Dynamic Testing

Tractor and triple axle double drop lowbed semi-trailer with power shovel, MTC = 69,320 kg

Measured Values	1st Test					2nd Test				
Type of manoeuvre	avoidance manoeuvre					braking				
Max. equivalent lat. acceleration (g)	0.16					-0.32 longitudinal				
Speed (km/h)	55					55				
Test number	test0					test0				
Tension in the chains (kN)	initial	minimum	maximum	spread	final	initial	minimum	maximum	spread	final
Front right tension (T1)	14.2	8.7	19.6	11.0	14.9	14.9	4.5	18.9	10.7	8.9
Front left tension (T2)	18.7	13.7	24.7	10.7	16.8	16.8	11.5	23.4	11.1	14.9
Rear right tension (T3)	6.7	0.7	14.7	13.4	4.5	4.1	4.1	8.1	4.0	6.7
Rear left tension (T4)	8.5	2.2	17.1	15.6	10.5	10.5	7.3	11.1	3.8	7.6
Load position (mm)	initial	minimum	maximum	spread	final	initial	minimum	maximum	spread	final
Front lateral position (D1)	-0.1	-0.6	0.4	0.9	0.1	0.1	-0.2	0.1	0.3	0.3
Rear lateral position (D2)	0.1	-0.2	0.2	0.4	0.1	0.1	-0.1	0.1	0.3	0.0
Longitudinal position (D3)	-2.3	-2.4	-2.2	0.1	-2.3	-2.3	-3.1	-2.3	0.5	-2.8

Measured Values	3rd Test					4th Test				
Type of manoeuvre	avoidance manoeuvre					avoidance manoeuvre				
Max. equivalent lat. acceleration (g)	0.16					0.18				
Speed (km/h)	53					60				
Test number	test2					test3				
Tension in the chains (kN)	initial	minimum	maximum	spread	final	initial	minimum	maximum	spread	final
Front right tension (T1)	13.4	7.7	20.5	20.0	13.4	13.4	7.6	19.5	12.5	13.4
Front left tension (T2)	17.8	12.5	24.5	11.1	15.6	17.8	11.6	23.8	11.1	16.9
Rear right tension (T3)	7.6	0.9	1.0	1.4	4.5	7.0	0.7	15.6	15.2	6.7
Rear left tension (T4)	6.7	2.0	3.3	3.3	9.9	6.7	1.1	17.8	16.0	8.5
Load position (mm)	initial	minimum	maximum	spread	final	initial	minimum	maximum	spread	final
Front lateral position (D1)	0.0	-0.5	0.4	0.3	0.1	0.0	-0.5	0.5	1.0	0.1
Rear lateral position (D2)	0.2	-0.8	0.3	0.4	0.2	0.2	-0.2	0.4	0.5	0.3
Longitudinal position (D3)	-2.7	-2.8	-2.7	1.0	-2.8	-2.8	-2.9	-2.7	0.3	-2.8

Measured Values		5th Test					6th Test				
Type of manoeuvre		avoidance manoeuvre					avoidance manoeuvre				
Max. equivalent lat. acceleration (g)		0.18					0.22				
Speed (km/h)		64					70				
Test number		test4					test6				
Tension in the chains (kN)		initial	minimum	maximum	spread	final	initial	minimum	maximum	spread	final
Front right tension (T1)		12.0	2.2	1.95	12.5	13.4	13.4	5.3	20.9	15.2	13.4
Front left tension (T2)		17.7	11.1	23.4	11.5	16.0	16.0	8.9	23.6	14.9	15.6
Rear right tension (T3)		8.0	0.9	15.6	15.2	5.3	5.7	0.4	17.8	17.8	5.7
Rear left tension (T4)		5.9	2.2	17.0	15.6	8.0	7.2	0.5	20.4	19.5	6.8
Load position (mm)		initial	minimum	maximum	spread	final	initial	minimum	maximum	spread	final
Front lateral position (D1)		0.1	-0.3	0.6	1.3	0.1	0.1	-0.5	0.8	1.3	0.3
Rear lateral position (D2)		0.2	-0.1	0.3	0.5	0.1	0.1	-0.3	0.3	0.5	0.3
Longitudinal position (D3)		-3.1	-3.3	-3.0	0.3	-3.1	-0.2	-0.3	0.0	0.3	-0.2

Measured Values		7th Test					8th Test				
Type of manoeuvre		avoidance manoeuvre					avoidance manoeuvre				
Max. equivalent lat. acceleration (g)		0.28					0.29				
Speed (km/h)		75					79				
Test number		test7					test8				
Tension in the chains (kN)		initial	minimum	maximum	spread	final	initial	minimum	maximum	spread	final
Front right tension (T1)		12.0	4.5	22.3	18.8	13.4	11.1	4.5	22.7	17.8	11.1
Front left tension (T2)		17.7	8.0	24.9	17.8	13.4	15.6	7.6	24.8	18.2	17.8
Rear right tension (T3)		6.1	0.2	21.2	21.3	2.2	5.3	0.2	20.9	20.9	8.9
Rear left tension (T4)		6.0	0.2	24.9	24.8	11.1	6.0	0.2	24.8	24.8	3.4
Load position (mm)		initial	minimum	maximum	spread	final	initial	minimum	maximum	spread	final
Front lateral position (D1)		0.2	-0.8	1.0	1.8	0.3	0.3	-0.6	1.0	1.5	0.0
Rear lateral position (D2)		0.1	-0.6	0.3	0.8	0.0	-0.1	-0.6	0.1	0.5	-0.3
Longitudinal position (D3)		-0.1	-0.3	0.1	0.3	-0.1	-0.1	-0.3	0.2	0.4	-0.1

Measured Values		9th Test				10th Test					
Type of manoeuvre		avoidance manoeuvre				braking					
Max. equivalent lat. acceleration (g)		0.37				-0.33 longitudinal					
Speed (km/h)		83.5				71					
Test number		test9				test10					
Tension in the chains (kN)		initial	minimum	maximum	spread	final	initial	minimum	maximum	spread	final

Front right tension (T1)	12.0	2.0	24.0	23.3	15.6	11.1	3.7	16.8	13.1	11.1
Front left tension (T2)	15.6	4.9	27.1	22.3	12.5	15.6	9.9	18.2	8.9	15.1
Rear right tension (T3)	8.0	0.0	28.0	28.0	8.0	5.8	4.5	6.7	2.8	5.9
Rear left tension (T4)	6.2	0.0	29.8	29.8	4.5	5.1	4.5	6.7	2.1	5.1
Load position (mm)	initial	minimum	maximum	spread	final	initial	minimum	maximum	spread	final
Front lateral position (D1)	0.5	-0.9	1.7	2.5	0.9	0.4	0.3	0.4	0.1	0.4
Rear lateral position (D2)	-0.5	-1.7	0.0	1.8	-0.5	-0.4	-0.8	-0.3	0.4	-0.4
Longitudinal position (D3)	-0.1	-0.3	0.3	0.1	-0.1	0.0	-0.8	0.1	0.8	-0.3

Measured Values	11th Test					12th Test				
Type of manoeuvre	constant radius					constant radius				
Max. equivalent lat. acceleration (g)	0.10					0.16				
Speed (km/h)	0 to 23					6 to 30				
Test number	test11					test12				
Tension in the chains (kN)	initial	minimum	maximum	spread	final	initial	minimum	maximum	spread	final
Front right tension (T1)	11.1	8.0	11.4	4.0	8.4	10.7	5.8	10.2	4.9	7.6
Front left tension (T2)	15.6	14.8	18.3	3.5	18.2	16.0	16.0	4.5	4.5	18.7
Rear right tension (T3)	3.5	3.5	7.8	4.5	7.1	4.5	4.5	12.0	6.7	8.9
Rear left tension (T4)	6.2	3.3	6.2	3.1	3.7	5.8	1.1	6.1	4.5	2.6
Load Position (mm)	initial	minimum	maximum	spread	final	initial	minimum	maximum	spread	final
Front lateral position (D1)	0.6	0.5	0.6	0.1	0.5	0.5	0.2	0.6	0.3	0.2
Rear lateral position (D2)	-0.1	-0.1	-0.1	0.0	-0.1	-0.1	-0.3	-0.1	0	-0.2
Longitudinal position (D3)	0.1	-0.0	0.1	0.0	0.1	0.0	0.0	0.1	0	0.1

Measured Values		13th Test			
Type of manoeuvre		constant radius			
Max. equivalent lat. acceleration (g)		0.09			
Speed (km/h)		27 to 37			
Test number		test13			
Tension in the chains (kN)		initial	minimum	maximum	spread
Front right tension (T1)		8.0	4.5	8.0	3.1
Front left tension (T2)		17.8	17.8	22.0	4.0
Rear right tension (T3)		8.0	8.0	15.6	6.7
Rear left tension (T4)		3.4	0.9	3.3	2.7
Load position (mm)		initial	minimum	maximum	spread
Front lateral position (D1)		0.3	-0.1	0.3	0.4
Rear lateral position (D2)		-0.2	-0.3	-0.2	0.0
Longitudinal position (D3)		0.1	0.1	0.2	0.0
				final	final
					11.1
					14.6
					6.0
					4.2
					-0.1
					-0.3
					0.1

## APPENDIX 5

The dimensions are shown in metres

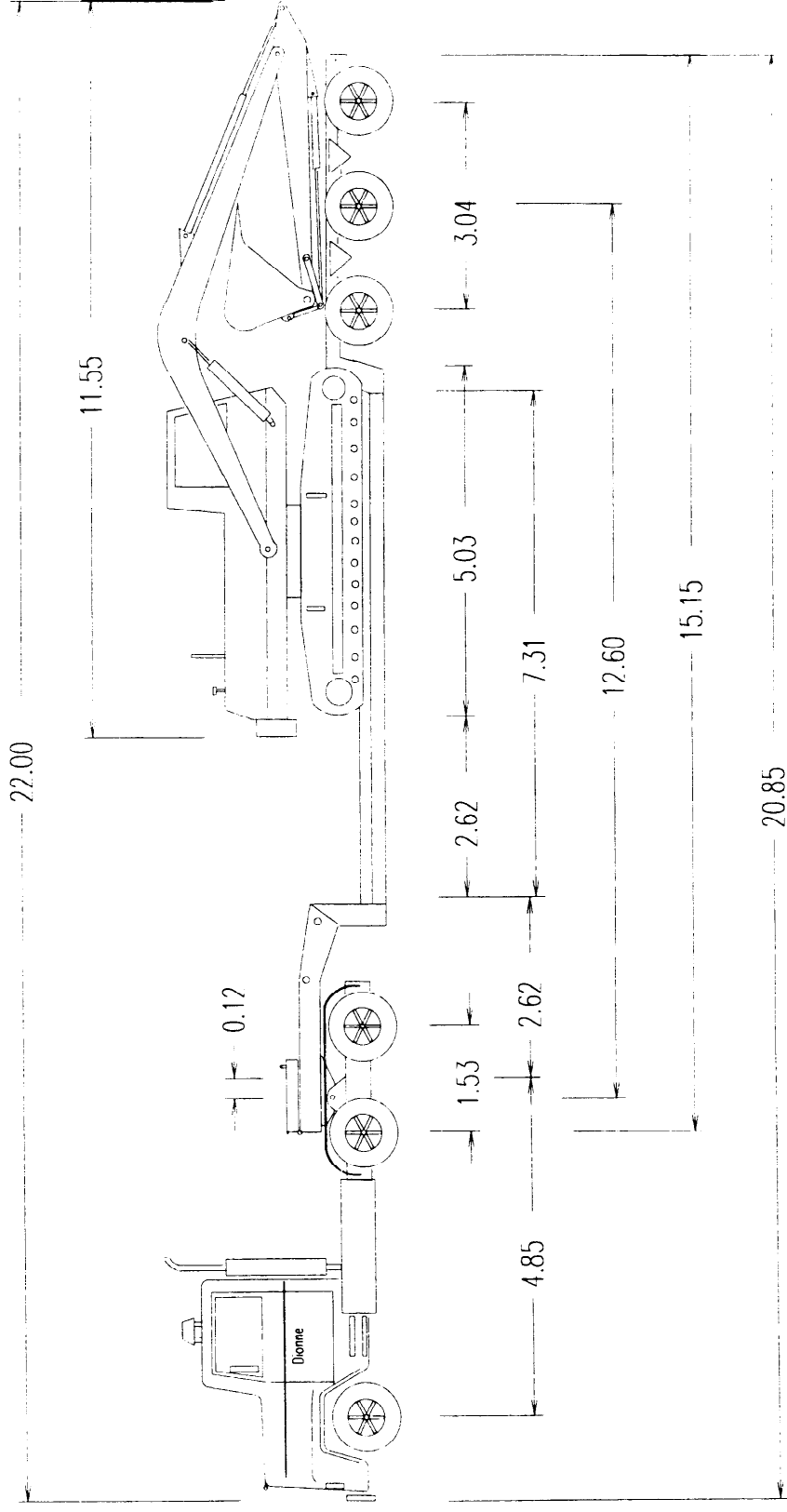


Figure 4: Dimensions of the tractor and double drop lowbed semi-trailer with power shovel used for the tests.

## APPENDIX 6



Photo 5: Securement at the front of the double drop lowbed.

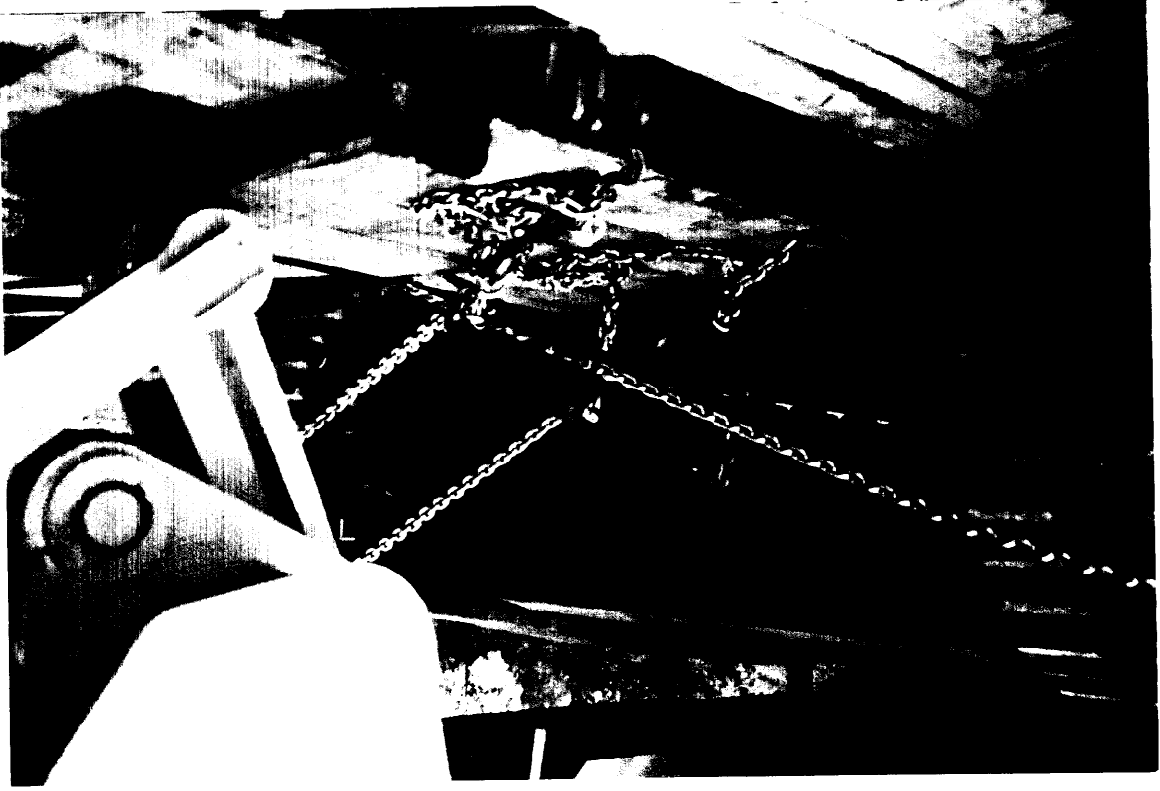


Photo 6: Securement at the rear of the double drop lowbed.

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- [1] Billing J.R., Mercer W.R.J. and Cann W., "A Proposal for Research to Provide a Technical Basis for a Revised National Standard on Load Security for Heavy Trucks", Transportation Technology and Energy Branch, Ontario Ministry of Transportation, Report CV-93-02, November 1993.

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- [3] Heidersdorf E. and Hay E., "Slippage Tests with Anti-skid Mats", North American Load Security Research Project, Report 3, Canadian Council of Motor Transport Administrators, Ottawa, Ontario, 1997.
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